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# CROP PRODUCTION ON IRRIGATED HEAVY TEXTURED SALINE SOILS WITH PARTICULAR REFERENCE TO THE VAL MARIE IRRIGATION PROJECT[1]

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The Val Marie Irrigation Project in Southwestern Saskatchewan was started in 1935 as part of the Prairie Farm Rehabilitation program. Most of the land was not irrigated until 1938 and development and settlement work has continued since then. At present the project is devoted principally to the production of forage crops.

Approximately 5,000 irrigable acres were included in the project and of this total about 1,300 acres of land were saline, very heavy clays which in the native state were dominated by greasewood (*Sarcobatus vermiculatus* (Hook) Torr.). This part of the project was designated the Greasewood Area. From the outset, it appeared to present special problems which were emphasized further by a soil survey conducted in 1936 (18). In order to obtain information as to whether or not this type of land could be brought under irrigation successfully, a representative experimental area was selected in 1937. This area was placed under supervision of the Division of Forage Crops, Dominion Experimental Station, Swift Current, and investigations relating to crop production and to cultural and irrigation practices were started. This paper summarizes the work conducted from 1938 to 1943. Wherever possible, experimental designs capable of being treated statistically were used and yield data were recorded and analysed. However, observational records were found, in many cases, to be the best way to study a particular problem and consequently certain conclusions are based largely on this method.

## DESCRIPTION OF THE AREA

The Val Marie Irrigation Project is located in Townships three and four of Ranges 13 and 14, all West of the Third Meridian. It is situated in the valley of the Frenchman River which rises in the Cypress Hills and flows southeasterly into the State of Montana, ultimately joining the Milk River.

Meteorological records indicate an annual average precipitation of 12 to 14 inches, an average annual temperature of 36 degrees Fahrenheit and an average frost-free period of 110 to 115 days.

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TABLE 1.—MECHANICAL ANALYSES OF SAMPLES—GREASEWOOD AREA

| Sample number | Depth | Per cent clay less than .002 mm. | Per cent silt .002 – .02 mm. | Per cent sand greater than .02 mm. |
|---|---|---|---|---|
| 1 | 0 – 8 | 65 | 23 | 12 |
| 2 | 0 – 8 | 66 | 24 | 10 |
| 3 | 0 – 8 | 65 | 21 | 14 |
| 4 | 0 – 8 | 66 | 24 | 10 |

The Greasewood Area of the project, in the native state, was covered by typical halophytic species of which the greasewood plant (*Sarcobatus vermiculatus*) was dominant. This is a spiny, perennial shrub which grows from two to four feet tall. Other halophytes present were: silvery atriplex (*Atriplex argentea* Nutt.), halberd-leaved atriplex (*A. hastata* L.), Nuttall's atriplex (*A. Nuttallii* S. Wats.), spear-leaved goosefoot (*Monolepis Nuttalliana* (Schult.) Greene), erect sea blite (*Suaeda erecta* (A. Nels) S. Wats.), saltgrass (*Distichlis stricta* (Torr.) Rydb.), Nuttall's alkali grass (*Puccinellia Nuttalliana* (Schultes) Hitch.) and poverty weed (*Iva axillaris* Pursh.). Western wheatgrass (*Agropyron Smithii* Rydb.), which is common on upland soils in this area, was found also to some extent. In less saline locations hoary sagebrush (*Artemisia cana* Pursh.) was dominant.

The topography of the land is flat. Some parts were cut up by water courses and small hummocks occurred in a few places.

FIGURE 1. The greasewood plant (*Sarcobatus vermiculatus* (Hook) Torr).

TABLE 2.—VARIABILITY IN SOLUBLE SALTS—GREASEWOOD AREA*

(Samples taken 30 feet apart, forage crop plots—1938)

| Sample number | Depth | $Na_2CO_3$ | $NaHCO_3$ | NaCl | $CaSO_4$ | $MgSO_4$ | $Na_2SO_4$ | Total |
|---|---|---|---|---|---|---|---|---|
| 252 | 0– 6 | — | 0.045 | 0.005 | 0.030 | 0.030 | — | 0.083 |
| 253 | 6–12 | — | 0.084 | 0.006 | 0.030 | — | — | 0.120 |
| 254 | 12–24 | — | 0.090 | 0.015 | 0.027 | — | — | 0.132 |
| 255 | 24–36 | — | 0.070 | 0.015 | 0.037 | 0.009 | 0.059 | 0.190 |
| 256 | 0– 6 | — | 0.076 | 0.014 | 0.027 | 0.003 | 0.004 | 0.124 |
| 257 | 6–12 | — | 0.054 | 0.025 | 0.131 | 0.109 | 0.512 | 0.831 |
| 258 | 12–24 | — | 0.035 | 0.016 | 0.719 | 0.456 | 0.842 | 2.065 |
| 259 | 24–36 | — | 0.098 | 0.012 | 0.370 | 0.317 | 0.734 | 1.469 |
| 260 | 0– 6 | — | 0.098 | 0.003 | 0.039 | 0.021 | 0.023 | 0.184 |
| 261 | 6–12 | — | 0.101 | 0.018 | 0.014 | 0.009 | 0.123 | 0.265 |
| 262 | 12–24 | — | 0.032 | 0.015 | 0.534 | 0.347 | 0.657 | 1.585 |
| 263 | 24–36 | — | 0.034 | 0.012 | 0.654 | 0.388 | 0.676 | 1.764 |
| 264 | 0– 6 | — | 0.043 | 0.008 | 0.040 | 0.021 | 0.018 | 0.130 |
| 265 | 6–12 | — | 0.092 | 0.012 | 0.032 | 0.016 | 0.067 | 0.219 |
| 266 | 12–24 | — | 0.047 | 0.007 | 0.200 | 0.125 | 0.453 | 0.832 |
| 267 | 24–36 | — | 0.030 | 0.008 | 0.734 | 0.329 | 0.500 | 1.601 |

* Amount of salts in per cent.
Data supplied by Soils Research Laboratory, Swift Current, Sask

FIGURE 2. General view of the Greasewood Area at Val Marie prior to cultivation. Greasewood plants are dominant but some other saline indicator species are present also.

The soils of the Greasewood Area are alluvial, recent in origin and probably derived from Cretaceous shales. They are classified as very heavy clays (18), (Table 1). There is a thin platy mulch on the surface and a hard cloddy structure below. This structure disperses readily when wetted resulting in a poor physical condition, the degree of dispersion varying inversely with the concentration of soluble salts. The moisture equivalent is high so that a large percentage of the water held by the soil is unavailable for plant growth. The surface layer of heavy clay, which varies from 20 to 36 inches deep, is usually underlain by siltier and more friable material.

In most respects the soils are of low fertility. The organic matter content is around two per cent, total nitrogen varies from 0.120 to 0.200 per cent while total phosphorus is fairly high, averaging 0.070 per cent. Easily soluble phosphorus is high also and ranges from 180 to 250 parts per million. Supplies of sulphur, calcium, magnesium, iron and other elements essential for plant growth appear to be adequate.

The concentration of soluble salts is relatively low in surface samples but high in the lower strata. The sulphates of calcium, magnesium and sodium predominate so that the soils may be classified as saline or "white alkali" types. Traces of sodium carbonate are infrequently found. The pH ranges from 7.8 to 8.4 and occasionally up to 8.8 or 9.0. The soluble salt content is characterized by extreme variability within short distances. This, as well as the nature and amount of salts present, is illustrated by data presented in Table 2.

## PROBLEMS OF CROP PRODUCTION

The Greasewood Area at Val Marie presented many difficult problems in relation to crop production. The initial problem was to determine a satisfactory method of obtaining stands of various crops, particularly those with smaller seeds. Moisture from rainfall or irrigation causes swelling and slaking of the soil resulting in poor moisture penetration and the exclusion of air. On drying, a thin surface crust forms which is hard and impenetrable. Later, cracks develop which probably damage the root systems of plants.

A wide range of crops was tested to determine those best suited to the soil and climatic conditions. Cultural experiments were conducted to determine suitable cropping practices; whether crop production could be maintained at a satisfactory level; the value of fertilizers and other soil amendments, and methods of soil improvement.

The topographical features of the land presented problems in regard to irrigation practices and drainage.

## LITERATURE

Large areas which support a greasewood vegetation occur in the Western United States, chiefly in narrow irrigated valleys. Kellog (12) states that the principal areas are in parts of Utah, Northern Montana and the Bighorn Basin of North Central Wyoming. Such lands are known to occur also in California, Nevada, Colorado, Arizona and New Mexico.

In the United States the greasewood plant grows on a wide range of soils, but more frequently on areas of finer textured and medium textured soils with fine textured imperfectly drained subsoils. According to Kearney et al (9) and Shantz (22) its presence usually indicates moderate to relatively heavy concentrations of salts in the soil. Magistad (13) states that such soils may often be reclaimed for irrigation depending upon the possibilities of drainage and the quality of the irrigation waters. This has been accomplished in the Price Area of Utah according to Rasmussen (21) over a long period of time.

In Canada, greasewood land has been encountered in the development of the Val Marie, Eastend and Maple Creek Irrigation Projects. Similar areas, not necessarily supporting a greasewood vegetation, exist throughout the drier portions of Saskatchewan and Alberta on low-lying saline lands. Other references dealing with particular phases will be introduced in the sections to which they are most pertinent.

## CULTURAL INVESTIGATIONS

### *Methods of Obtaining Stands of Forage Crops*

At the outset of the experimental work at Val Marie, it was found difficult or impossible to obtain satisfactory stands of forage crops by standard methods. This was particularly true of small seeded crops. The principal difficulty was related to the physical nature of the soil. A surface crust forms, following a rain or irrigation, which prevents seedling emergence. Seedlings which do emerge come up through cracks, and hence there are seldom enough to produce a satisfactory stand.

FIGURE 3. Comparative stand of Reed canary grass (*left*) and timothy (*right*). Stands of small seeded crops are difficult to establish.

FIGURE 4. Alfalfa drilled (*left*) and broadcast (*right*). The broadcast stand is considerably thicker.

Another factor involved is soil temperature. In common with heavier soils, this is low in the spring and the soils are slow to warm up. As a result, germination and subsequent growth are delayed. Since it is not possible to cultivate the soil with machinery when the surface is moist, seeding must always be done in dry soil and a good rain or irrigation is required for germination. By the time seeds placed as shallow as one inch have germinated, a surface crust has already formed.

In addition to the crusting problem and low soil temperatures, the soluble salt content of the soils probably results in a certain amount of seedling mortality.

Some doubts existed as to whether or not it would be possible to grow certain forage crops because of the difficulty encountered in establishing them. As the area was being developed principally for forage crop production, and since it was considered that this class of crops would be best suited to the soil conditions, the problem was serious and was the first which had to be solved. Consequently, several tests were conducted to determine a satisfactory method of seeding.

Various implements were used following drilled seedings after a crust had formed and when the surface soil was dry enough to permit working. This proved to be of no value since too long a period elapsed before machinery could be put on the land. By this time, the seedlings had been destroyed by the crust.

Some success was obtained by frequent irrigations following seeding. This practice kept the soil moist continually and prevented crust formation. The results were variable, however, and success appeared to depend upon being able to irrigate quickly and to obtain good drainage.

Mulches of straw and barnyard manure were tried after seeding and proved to be quite successful in preventing crusting. The principal objections to this method were the time required and the cost of applying the mulch. However, it was possible by this method to secure good stands of brome, slender wheatgrass, timothy, alfalfa and sweet clover.

Commercial fertilizers were drilled in with the seed to determine their value in obtaining stands. The fertilizers used were triple superphosphate, ammonium phosphate and a N.P.K. fertilizer. These were applied at rates of 50 and 100 pounds per acre. There was no evidence of increased emergence as a result in comparison to the untreated seedings.

Companion crops of oats and wheat were tried with crested wheatgrass and alfalfa. Equal or better stands were secured in all cases where companion crops were not used. The companion crops were of no apparent value in assisting the small seedlings to penetrate the soil crust.

Good stands were secured in several cases by drilling forage crop seed into grain stubble. Less crusting was evident here and the stubble appeared to act as a mulch.

The most successful and practical method of obtaining a satisfactory stand was by broadcast seedings. In 1939, broadcast seedings of crested wheatgrass and alfalfa were made in September. On half of each plot one stroke of the drag harrow was given following seeding, while on the other half drag chains were left to do the covering. Two rates of seeding, 10 and 20 pounds per acre, were used for each crop and treatment, and an irrigation was given following seeding. Emergence of alfalfa began on the third day and was complete at the end of the fifth day. Crested wheatgrass began emerging on the fifth day after irrigating and by the seventh day enough seedlings were showing to produce good stands. Sufficient seedlings emerged from both rates of seeding to give satisfactory stands although the 20 pound rate was thicker. It was noted that the majority of seedlings emerged through the unbroken surface rather than through cracks in the soil as in the case of drilled seedings.

The experiment was repeated in the spring of 1940 with similar results, and consequently this method was used extensively that year when over 1000 acres of the Greasewood Area were seeded to forage crops. In most cases where broadcast seeding was done, good results were obtained. By this method excellent stands of alfalfa, sweet clover, crested wheatgrass, slender wheatgrass, brome, meadow fescue, Reed canary grass and various mixtures were secured.

Based on the results of the 1939 and 1940 experiments a very successful seeding technique was developed. The seed is broadcast on a relatively firm seed bed which has a roughened surface. No post seeding treatment such as harrowing is given. When rain falls or an irrigation is given, the roughened surface slakes down to form a thin covering over the seed. Since the seeds are close to the surface, germination is rapid and the seedlings emerge before crust formation begins. The best stands are obtained when rainfall induces germination; hence irrigation following seeding is delayed as long as possible. However irrigating, if properly done, also produces good stands. Frequently only enough rain falls to induce partial

germination, or to promote good germination, but is insufficient to connect with subsoil moisture. In such cases, it is necessary to irrigate. Proper drainage is particularly essential at this stage.

Broadcast seeding is done in the spring from May 15th to June 15th. There does not appear to be any advantage in seeding earlier as soil temperatures are low during the early spring. In addition, most of the spring rainfall comes in this period; thus it is the most favourable time for germination. Late and early fall seedings were not so successful as spring seedings.

With broadcast seedings, the rate is increased about 25 per cent above recommended rates on average soils.

*Experiments with Companion Crops*

In 1940, an experiment was conducted to determine the value of companion crops. Oats were seeded at rates of one, one and one-half and two bushels per acre with check plots between each rate of seeding. Alfalfa was then broadcast over the seeded and check strips. Excellent stands of alfalfa were secured on all treatments but later in the season the advanced maturity of the alfalfa seeded alone was evident. There appeared to be about the same number of plants but those seeded without a companion crop had developed more shoots and the stand was thicker. Data from the test are presented in Table 3.

TABLE 3.—YIELD OF ALFALFA FOLLOWING A COMPANION CROP OF OATS

| Treatment | Yield of oats—bus. per acre, 1940 | Growth stage of alfalfa, fall of 1940 | Yield of alfalfa—tons per acre, 1941 |
|---|---|---|---|
| Oats—1 bus. per acre | 53.3 | Pre-flowering stage | 1.78 |
| Oats—1½ bus. per acre | 72.1 | Pre-flowering stage | 1.36 |
| Oats—2 bus. per acre | 77.3 | Pre-flowering stage | 0.94 |
| Alfalfa alone | — | Setting seed | 2.09 |

The experiment was repeated in 1941 and 1942 with similar results. It was concluded that companion crops of oats are of no value in securing alfalfa stands and may reduce the yield in subsequent years.

*Experiments on Fall and Spring Ploughing*

The beneficial effect of fall ploughing on heavier soils is mentioned by Keen (11), Baver (1) and others. Fall ploughing is a recognized agricultural practice in many regions and produces a friable easily tilled soil in the spring because of the effect of alternate freezing and thawing which results in granulation of the soil separates.

In order to test the possible effect of fall ploughing, half of a strip was ploughed in the fall of 1939 and the other half spring ploughed in 1940. The entire strip was worked down, levelled and seeded to oats. Paired samples were harvested from the two treatments and the data are presented in Table 4. In this test, fall ploughing resulted in a tremendous yield increase.

TABLE 4.—FALL PLOUGHING VS. SPRING PLOUGHING ON OATS

| Treatment | Yield, bushels per acre | t Value* |
|---|---|---|
| Fall plowed | 97.8 | 15.31 |
| Spring plowed | 50.5 | — |

* Values of t greater than 2.3 are significant.

The principle of fall cultivation was tested further in 1941 when millet, alfalfa and sweet clover were seeded. Hay samples were taken from these plots in the fall of the year of seeding. The data are shown in Table 5. Fall ploughing resulted in significant increases in yield for sweet clover and alfalfa as compared with spring ploughing. Millet yields were lower on spring ploughing but not significantly so.

TABLE 5.—YIELD OF HAY ON SPRING AND FALL PLOWED PLOTS

| Crop | Treatment | Tons of hay per acre | t Value* |
|---|---|---|---|
| Alfalfa | Fall plowed | 1.18 | |
| | Spring plowed | 0.88 | 9.08 |
| Sweet clover | Fall plowed | 0.91 | |
| | Spring plowed | 0.66 | 3.57 |
| Millet | Fall plowed | 0.91 | |
| | Spring plowed | 0.66 | 1.13 |

* Values of t greater than 2.3 are significant.

## CROP SEQUENCE STUDIES

In the first test of this nature, oats were sown in 1941 on plots which had received the following treatments:

(1) Summerfallowed in 1939 and 1940
(2) Manured in 1939 and summerfallowed in 1940
(3) Seeded to sweet clover in 1939 and plowed under in 1940
(4) Manured in 1939, seeded to sweet clover which was plowed under in 1940.

A summary of the data obtained is presented in Table 6. Although the oat yields were fairly high, there were no significant differences between treatments.

TABLE 6—YIELD OF OATS FOLLOWING DIFFERENT SOIL TREATMENTS

| Previous treatment | Yield of oats bushels per acre |
|---|---|
| Summerfallowed | 63.1 |
| Summerfallowed and manured | 65.3 |
| Sweet clover | 68.5 |
| Sweet clover and manured | 63.8 |

In the second test in 1943, oats were sown on plots that had been down to crested wheatgrass and alfalfa for three years previously. The yield data from this test, given in Table 7, indicate a beneficial effect from alfalfa as compared to the grass.

TABLE 7.—YIELD OF OATS FOLLOWING CRESTED WHEATGRASS AND ALFALFA

| Previous treatment | Yield of oats, bushels per acre |
|---|---|
| Crested wheat—3 years | 29.6 |
| Alfalfa —3 years | 42.3 |

Difference significant at the 1 per cent point.

In 1943, soil samples were collected from adjacent plots which had been cropped differently. The averages of these analyses, presented in Table 8, suggest an increased content of nitrogen and organic matter on the sweet clover plots.

TABLE 8.—ANALYSES OF SOIL SAMPLES—VAL MARIE EXPERIMENTAL AREA

(Surface 8-inch depth)

| Soil treatment | Nitrogen in per cent | Organic matter in per cent | Total salt in per cent |
|---|---|---|---|
| Sweet clover —2 years | .160 | 2.654 | .352 |
| Alfalfa —3 years | .140 | 2.263 | .356 |
| Oats —4 years | .136 | 2.255 | .328 |
| Crested wheat—3 years | .155 | 2.535 | .260 |

*Control of Poverty Weed*

Poverty weed (*Iva axillaris* Pursh.) is a native perennial plant on the Greasewood Area. It occurs in small patches which may cover only a few square feet or may stretch over an acre or more. The plant has creeping rootstocks and invades adjacent areas more in this manner than by seed. It is not affected appreciably by drought, prolonged flooding or intensive cultivation and is difficult to control. It appears to be particularly adapted to heavy clay soils and constituted the major weed problem at Val Marie.

No definite experiments were undertaken to determine control measures but in the course of other experiments it was found that perennial forage crops such as alfalfa, slender wheatgrass, brome and crested wheatgrass would control this weed. It was usually difficult to obtain a stand of the perennial crop in poverty weed patches. Fall ploughing appeared to weaken the poverty weed and this, followed by early spring seeding, enabled the the control crop to get a good start. A slightly higher rate of seeding was used in these patches and it was necessary to irrigate frequently since the weed was a strong competitor for moisture. Complete control, after a stand had been established, required about three years.

FIGURE 5. Discing land prior to seeding—1941.

FIGURE 6. Oat crop on the experimental area—1941.

*Methods and Machinery for Cultivation*

An experiment was conducted in 1938 to determine the value of different implements as measured by the yield of oats. In preparation for irrigation, the land was first cleared of brush with the Noble blade weeder which also cultivated the land to a depth of four to six inches. Following this operation the land was levelled and seeded. A series of strips were treated to compare this general method of land preparation with the use of various implements before and after seeding. The results are given in Table 9 and they indicate no apparent benefit from the different methods of cultivation. However, in no case was the yield appreciably lower than on the uncultivated strips except when a drag harrow was used following irrigation and when the oats were in the three leaf stage.

TABLE 9.—THE EFFECT OF VARIOUS IMPLEMENTS ON THE YIELD OF OATS

| Treatment | Yield of oats, bushels per acre |
|---|---|
| Seed and duckfoot cultivate | 57.8 |
| Duckfoot cultivate and seed | 53.3 |
| Seed only | 56.6 |
| Seeded, packed after irrigation | 62.0 |
| Seeded, drag harrowed when oats in three leaf stage | 43.1 |
| Seeded, drag harrowed after irrigation | 43.0 |

Not all implements were found to be suitable for the soils of the Greasewood Area. A disc harrow was possibly the most useful implement for surface tillage work, although the duckfoot cultivator was satisfactory providing the surface soil was quite dry. In general the one-way disc was not suitable, and considerable difficulty was usually experienced in getting it to work well. Most types of seed drills were satisfactory providing the soil was not too moist.

The mouldboard plow was suitable although difficulty was experienced because of non-scouring if the soil was too wet and in keeping the plow in the ground when the soil was too dry. There was a narrow range of soil moisture content at which a good ploughing job could be done. With a 15-horse power tractor, one 16-inch bottom plough appeared to be the best combination. While it was possible to pull two 14-inch bottom ploughs with this size of tractor, at times the power required exceeded the maximum drawbar horse-power which resulted in a poor job due to difficulty in maintaining the plough at an even depth. Because of the great variation in draft on these soils, it was necessary to have a large excess of power, and consequently ploughing was slow and expensive.

*Commercial Fertilizers*

Since the soils of the Greasewood Area are relatively low in fertility it might be expected that the application of commercial fertilizers would increase crop yields. Several tests were conducted to determine the value of fertilizers and, with one exception, they failed to produce significant increases. Data from a test with oats are shown in Table 10 and from another test with brome grass and crested wheatgrass in Table 11. In the latter test most of the yield increases were significant, but the general level of yields was low. Alfalfa and grass-legume mixtures did not respond to commercial fertilizers of various kinds at rates of 100 and 200 pounds per acre, although it would seem natural to expect that they would after the land had been cropped for a number of years.

Several greenhouse experiments[1] were carried out and, in these, commercial fertilizers gave variable results. In several cases yield increases were obtained. These increases were most pronounced with the first crop grown and subsequent crops frequently yielded lower than the untreated checks. Nitrate fertilizers produced the largest increase in yield.

Calcium sulphate, elemental sulphur, ground limestone, calcium carbonate and air-slaked lime were all tested in greenhouse pot experiments. None of these had any notable effect on crop yields excepting in some cases with the first crop. In these cases the following crops were lower yielding than the checks. Similar results were obtained with manure in pot experiments.

The improvement of crop yields on these soils appeared to be related primarily to improvement in the physical nature of the soils. With continued cropping soil amendments would undoubtedly be required to maintain yields.

[1] Most of the greenhouse work with the Greasewood Area soils was conducted by the Soils Research Laboratory, both independently and co-operatively with the authors.

TABLE 10.—FERTILIZER TEST ON OATS—1938

| Fertilizer | Yield of oats bushels per acre. |
|---|---|
| Superphosphate | 25.6 |
| Check—No fertilizer | 17.3 |
| Ammonium phosphate 11–48–0 | 29.2 |
| Check—No fertilizer | 30.4 |
| Ammonium sulphate | 20.1 |
| Check—No fertilizer | 24.8 |

Fertilizers applied at rate of 50 pounds per acre.

TABLE 11.—FERTILIZER TEST OF BROME AND CRESTED WHEATGRASS—1940

| Crop | Fertilizer | Rate pounds per acre | Tons per acre | | Yield as per cent of check | t** Values |
|---|---|---|---|---|---|---|
| | | | Yield of treated plot | Yield* of check | | |
| Crested wheat | Ammonium sulphate | 115 | 0.74 | 0.50 | 148 | 4.80 |
| | Ammonium phosphate 11-48-0 | 115 | 0.71 | 0.42 | 169 | 10.08 |
| | Sodium nitrate | 115 | 0.56 | 0.41 | 137 | 3.88 |
| | Borax | 35 | 0.35 | 0.39 | 90 | 2.09 |
| | Ammonium sulphate | 345 | 0.60 | 0.35 | 171 | 6.31 |
| | Ammonium phosphate 11-48-0 | 345 | 0.54 | 0.43 | 126 | 2.41 |
| | Sodium nitrate | 345 | 0.76 | 0.49 | 153 | 5.84 |
| | Complete 9-27-9 | 200 | 0.59 | 0.48 | 123 | 2.81 |
| Brome | Ammonium sulphate | 115 | 0.95 | 0.81 | 117 | 2.25 |
| | Ammonium phosphate 11–48–0 | 115 | 0.78 | 0.59 | 132 | 3.95 |
| | Sodium nitrate | 115 | 0.51 | 0.40 | 128 | 2.40 |
| | Borax | 35 | 0.39 | 0.40 | 98 | — |
| | Ammonium sulphate | 345 | 0.76 | 0.41 | 185 | 8.63 |
| | Ammonium phosphate 11–48–0 | 345 | 0.72 | 0.41 | 176 | 7.14 |
| | Sodium nitrate | 345 | 0.75 | 0.41 | 183 | 8.29 |
| | Complete 9–27–9 | 200 | 0.44 | 0.43 | 102 | — |

* The yield of the check consists of the average of the two check plots on each side of the treated plot.
** Values of t greater than 2.31 exceed the 5 per cent point and such differences are significant. The 1 per cent point is 3.36.

## ALFALFA SEED PRODUCTION

During the period 1938–1943 at Val Marie it was observed that alfalfa set seed freely, excepting in one year, and this suggested that seed production might be a profitable enterprise. It was observed also that there was considerable variability in seed yields between different fields in the same year and these differences seemed to be related to the thickness of the stand and to the irrigation practice followed. A row spacing experiment was started in 1941 and data for the following two years are presented in Table 12. The data indicate that higher seed yields could be obtained by growing the seed crop in one or two foot row spacings.

An irrigation test was conducted in 1943 in which seed plots were watered in the spring, at flowering time, after flowering and in all possible combinations of these stages. In this test, with the exception of two treatments, negligible amounts of seed were harvested. The two treatments, where seed was produced, were irrigated two and three times respectively. In the first case, irrigation was done in the spring and at flowering time; and in the second case in the spring, at flowering time and after flowering. The seed yield was 185 pounds per acre for two irrigations and 225 pounds per acre for three irrigations. While the data cover one season only, they confirmed previous field observations which indicated that during dry years, even though other conditions for seed setting were favourable, alfalfa on these soils required an abundant and continuous supply of moisture in order to produce a good yield of seed. This might involve from two to three irrigations.

FIGURE 7. First cutting of alfalfa hay, experimental area—1942.

TABLE 12.—YIELD OF ALFALFA SEED
(Pounds per acre)

| Year | 6-inch rows | 1-foot rows | 2-foot rows | 3-foot rows |
|---|---|---|---|---|
| 1942 | 160.9 | 192.4 | 209.5 | 173.0 |
| 1943 | 236.2 | 302.8 | 289.2 | 207.3 |
| 2-year average | 198.6 | 247.6 | 249.3 | 190.1 |

## CROP TESTING

During the initial phases of the Val Marie investigations, a large number of crops were tested to determine those best suited to the soils and climatic conditions. Many proved to be unsatisfactory and were discarded, while those that showed promise were tested further in variety trials. In several cases the data obtained were insufficient to warrant definite conclusions.

No attempt will be made to review the comprehensive and frequently conflicting literature on the subject of crop tolerance to salinity and alkali (3, 7, 10, 17, 19, 23). Magistad and his associates (4, 5, 6, 14, 16) have shown that crop growth on saline and alkali soils is influenced by the nature and amount of salts present, the osmotic pressure of the soil solution, the physical nature of the soil, climate and other associated factors. Consequently, results obtained or observations made under a given set of conditions frequently have only limited local application. In general, on saline soils, perennial forage crops have been found to be best adapted although certain annual and biennial crops have been found to be suitable also.

FIGURE 8. Cutting a grass-legume mixture—1942; yield of 2.87 tons per acre.

*Annual Forage Crops*

A wide range of annual forages was tested over a four-year period. Of these oats, sorghum and millet were the only crops which produced well enough to merit consideration. Dakota Early Amber sorghum produced a three-year average yield of 2.82 tons per acre, Japanese millet a three-year average yield of 2.44 tons per acre and oats as a grain crop yielded from 40 to 100 bushels per acre in different years. Annual crops tested and considered to be unsuitable from a yield standpoint included wheat, barley, flax, rye, sugar beets, mangels, turnips, corn, rape, peas, vetch, soybeans, annual sweet clovers and Sudan grass.

*Perennial Grasses*

Several grasses were found to be satisfactory and the best of these were slender wheatgrass, brome grass, crested wheatgrass, meadow fescue and Reed canary. Tall oatgrass, creeping red fescue and timothy ranked next but were of secondary importance. Red top, Kentucky and Canada bluegrass seedings were not satisfactory.

It was particularly noted that while several grasses could be readily established, they produced well for only one year following seeding. The yield thereafter dropped sharply and the stands were unproductive. Most of the first established stands of slender wheatgrass, brome grass, crested wheatgrass, meadow fescue and Reed canary grass maintained themselves and did not noticeably thin out over a period of years but neither did they yield very much forage.

*Perennial and Biennial Legumes*

Alfalfa and sweet clover showed to best advantage in this group, both yielding well when properly irrigated and when good drainage could be obtained. The average yield of the better varieties of sweet clover

was from three to three and one-half tons per acre from one cutting and of alfalfa from three and one-half to four and one-half tons per acre from two cuttings. The yield of alfalfa was low during the first year or two after seeding and reached a maximum during the third, fourth and fifth years. Most of the true clovers were not winterhardy excepting alsike which usually survived and is a useful component of mixtures.

*Grass-Legume Mixtures*

The yields obtained from grass-legume mixtures on the soils of the Greasewood Area were a striking feature. As indicated previously, when grasses were grown alone the yields, while good the year following seeding, quickly dropped thereafter to a point where it was not economical to harvest a hay crop. When grasses such as brome grass or slender wheatgrass were grown in combination with alfalfa, the yields were maintained at a fairly high level for a number of years. A mixture consisting of slender wheatgrass, brome grass, crested wheatgrass, Reed canary grass, meadow fescue, alsike clover and alfalfa seeded on a 10-acre block produced a three-year average yield from one cutting of 2.40 tons per acre and maintained a complete stand.

*Land Utilization*

The soils of the Greasewood Area are difficult and costly to cultivate because of their physical nature. Considerable power is required for machinery operations which increases costs. In addition machinery can work well on this land only when the surface soil is fairly dry, with the result that during moister seasons spring operations are delayed considerably. Consequently, with the limited number of crops that can be grown, a system of diversified agriculture would not appear feasible for the present. The most economical method of land utilization is perennial crop production which will produce the greatest returns at the lowest cost. For this purpose, alfalfa and a few grasses are satisfactory. These may be grown for hay, pasture or seed.

As shown previously, alfalfa seed production has distinct possibilities in this area and there is some evidence that grass seed production would be successful and profitable. Aside from this, the principal use of the Greasewood Area would seem to be the production of hay and pasture crops. Insufficient data are available at present to indicate the yields of alfalfa that may be expected over a period of years, but observations on existing stands indicate that this crop by itself is not satisfactory on much of the Greasewood Area. Since the land is quite flat, complete surface drainage is difficult to secure. As a result alfalfa stands are frequently damaged when irrigated during hot weather, and completely killed out in low spots which pond water. This inability to secure quick and complete drainage of irrigation water eventually results in thin, patchy stands, the invasion of weeds and lowered yields of hay.

For most of the Greasewood Area a grass-legume mixture is the best crop to grow. Land which has poor surface drainage should be seeded to grasses such as slender wheatgrass, brome grass, meadow fescue and Reed canary which can tolerate excess water for longer periods than alfalfa (2).

Alfalfa should be used in the mixture and will persist wherever drainage is satisfactory. In low areas the grasses resistant to ponding will not be killed out and in this way a complete stand that prevents the establishment of weedy patches can be maintained. Data obtained show that average yields of two and one-half tons of hay per acre may be expected from such mixtures.

## IRRIGATION AND SALINITY STUDIES

### *Land Preparation*

In preparing land for irrigation it is essential that a thorough job of levelling be done before seeding to a perennial crop, particularly if the land has very little slope. Where this was done on the Greasewood Area, the least difficulty was experienced in regard to irrigation and drainage. The Noble blade weeder was used to remove the growth of sagebrush and greasewood after which the land was ploughed and levelled. Large automatic scrapers were used to fill in depressions but, where this was not necessary, logs, rails or automatic levellers were used. Ditching was done after the final levelling operation as this enabled large blocks to be levelled as a unit. A cereal crop was first seeded and, if the land proved to be satisfactorily prepared for irrigation, a perennial forage crop was then sown. Homemade wooden float levellers proved to be useful for yearly levelling operations.

### *Size of Ditches and Heads of Water*

Owing to the flatness of the land, it was found that large heads of water were necessary to irrigate quickly and effectively. Streams of water of four to six cubic feet per second were required. Streams of this size required field supply ditches of like capacity and lateral ditches capable of supplying 15 to 20 cubic feet per second so that as many as three streams of water could be used at one time. It was difficult to irrigate this land with small heads of two to three cubic feet per second as such streams resulted in uneven and slow irrigation. Particular attention had to be given to drainage for each parcel of land since it was imperative that surplus irrigation water be removed rapidly.

### *Methods of Irrigating*

The border method of irrigating was used extensively at Val Marie and was found to be well adapted to the topography of the land. The ditch and dike variations of the border method were both tried and found to have certain advantages and disadvantages. The main points in favour of the border ditch method were that, with an adequate head of water, irrigation could be done quickly, very little water was wasted and good drainage could be obtained. The principal disadvantage was that it wasted land, from 12 to 15 per cent being lost by ditches. In addition, the ditches required constant upkeep to maintain them in proper condition. Weed growth on the banks reduced the flow of water and was a source of infestation. While grassing the banks would control weeds, the water flow was still slowed down. It was found that strips a quarter of a mile long and 100 feet wide were suitable with this method.

The border dike method wasted almost no land; the dikes were more or less permanent and required little upkeep when properly made, and

FIGURE 9. Beet webworm damage on a first year stand of alfalfa—1940. Notice the cracked condition of the land following irrigation.

they could be seeded down to a crop. With this method, irrigation was done with a minimum of effort on the part of the irrigator who could handle several streams of water at the same time, particularly when checks were built in the supply ditches and box-turnouts installed for each strip. This method was cheaper than the border ditch method but was actually slower for a given quantity of water and more water was wasted. A major disadvantage was that drainage could not be accomplished effectively and hence this method was only suited to very well levelled land. The dimensions of border dike strips varied from 50 to 100 feet wide and from one-eighth to one-quarter mile long. Usually the shorter and narrower strips were most satisfactory.

The furrow and corrugation methods of irrigating were tried out but were not adaptable. The principal difficulty was that water would not flow down the furrows or corrugations because the land had so little slope.

*Penetration of Irrigation Water*

When auger borings were made in 1940 on plots of crested wheatgrass, brome grass and alfalfa, which had been flooded for a 21-day period, dry soil was encountered at a depth of 18 inches. Similar results were obtained later that year at other locations following irrigation. It appeared that moisture was unable to penetrate to any appreciable depth in these soils on account of their physical nature. At the time the borings were made, the land had been under cultivation for only one or two years.

FIGURE 10. Meadow fescue (*left*) and crested wheatgrass (*right*). Poor drainage of irrigation water has killed out the crested wheat while the meadow fescue is uninjured.

In 1943, an extensive series of borings were made on a number of crops after they had been irrigated. The plots sampled had been irrigated 15 to 20 times since being brought under cultivation, and had either been cropped annually or had a perennial crop growing on them for two to four years. Five to six days after irrigating, at which time it was assumed that maximum penetration had occurred, borings were made to a depth of five feet. The results of this study are summarized in Table 13. The poorest moisture penetration was found in alfalfa plots and the best in grass and continuous oat plots. Poor penetration was obtained in a pasture mixture when sampled near alfalfa plants and on an oat plot which had been previously in alfalfa. The results show that alfalfa was not so effective as grasses in improving water penetration on these soils. The results show also that while these soils were relatively impermeable to water at first, they gradually became permeable after growing grass crops for a few years.

It was noted in this study that the depth of root penetration corresponded closely to the depth of moisture penetration with the different crops sampled. Alfalfa was observed to be shallow rooted with a branching rather than a tap root system.

*Irrigation Practices for Alfalfa*

The most pertinent work on the irrigation requirements of alfalfa under climatic conditions similar to Val Marie was done by Palmer (20) but on a lighter soil type. Four irrigations gave the highest five-year average yield of alfalfa followed closely even in dry years by three irriga-

TABLE 13.—DEPTH OF PENETRATION OF IRRIGATION WATER UNDER VARIOUS CROPS

| Crop cover of plot sampled | Days following irrigation when sampled | Maximum depth to which irrigation water penetrated (ins.) |
|---|---|---|
| Alfalfa | 10 | 12 |
| Alfalfa | 6 | 24 |
| Pasture mixture (near alfalfa plants) | 5 | 30 |
| Oats following alfalfa | 6 | 32 |
| Oats following crested wheat | 6 | 42 |
| Fallow after four years oats | 5 | 52 |
| Meadow fescue | 5 | 54 |
| Crested wheatgrass | 5 | 60* |
| Slender wheatgrass | 5 | 60* |
| Oats (three years continuous) | 5 | 60* |

* Indicates greater than 60 inches penetration.

tions. Two irrigations were sufficient in years of average rainfall. Palmer concluded that a fall irrigation was not so effective in producing a hay crop as the same irrigation given in the spring. He suggested irrigating in early May, again when the plants were 12 inches high if required, and again following the first cutting.

An experiment on the number of irrigations required for alfalfa was started at Val Marie but had to be abandoned due to technical difficulties. Field observations suggested that a schedule somewhat similar to that of Palmer's was required on these soils but, because of the impervious nature of the soils, one additional irrigation would be needed on the average each year. This would amount to three irrigations in moister years and four in the drier years. Because some winterkilling was experienced, fall irrigation would be desirable, enabling plants to make a good growth before freeze-up. A second irrigation could be given in May and a third, if necessary, in June. Usually the third irrigation would not be required until after the first hay crop had been cut. A fourth irrigation, given before the second cutting, would be needed in extremely dry years. In general, three to four irrigations would be necessary.

*Salinity and Crop Growth Relationships*

Data have been presented which show that the soluble salt content of the Greasewood Area soils was not excessive nor a serious limitation to crop growth. It was also pointed out that there is a considerable variation in salt content within short distances and that the salt content may be high enough in some locations to affect plant growth. This was observed more frequently with annual crops and was not so marked in perennials, although it was sometimes evident in alfalfa stands during the first and second years of growth. Soil samples were collected in 1941 from adjacent locations where good and poor growth of the same crops was found. These samples were analysed for salt content and the results are shown in Table 14. The analyses indicate a definite correlation between the type of plant growth and the amount of salts present.

TABLE 14—*VARIATION IN SALT CONTENT AND PLANT GROWTH**

| Crop | Depth | pH | Total salts | Total salts minus $CaSO_4$ |
|---|---|---|---|---|
| Corn, 54–60 ins. high | 0 – 12 | 8.08 | 1.490 | 0.908 |
| | 12 – 24 | 8.25 | 1.645 | 0.961 |
| Corn, 14–15 ins. high | 0 – 12 | 8.14 | 1.670 | 1.156 |
| | 12 – 24 | 8.48 | 2.015 | 1.580 |
| Good oats, 36–42 ins. high | 0 – 12 | 8.22 | 0.244 | 0.230 |
| | 12 – 24 | 8.12 | 1.956 | 1.296 |
| Poor oats, 15–18 ins. high | 0 – 12 | 8.06 | 1.021 | 0.882 |
| | 12 – 24 | 8.08 | 1.806 | 1.157 |
| Good oats, 42–48 ins. high | 0 – 12 | 8.30 | 0.225 | 0.195 |
| | 12 – 24 | 8.16 | 0.280 | 0.250 |
| Poor oats, 24 ins. high | 0 – 12 | 8.04 | 1.930 | 1.388 |
| | 12 – 24 | 8.22 | 2.000 | 1.504 |

* Data supplied by the Soils Research Laboratory, Swift Current.
** Amount of salts in per cent

*Quality of Irrigation Water*

The use of irrigation waters containing too much soluble salts has resulted in the abandonment of many irrigation projects or parts thereof as well as reduction in crop yields. A close check was kept on the quality of irrigation water being supplied at Val Marie. A summary of these analyses is presented in Table 15. The salt content of these samples is considerably below the limits set by Hilgard (8) and below the upper limits of Class I irrigation water as defined by Magistad and Christiansen (15) which they term excellent to good. The amount of salts being brought in by irrigation water is relatively negligible and unlikely to aggravate the salinity problem on these soils.

TABLE 15.—ANALYSES OF WATER SAMPLES—VAL MARIE STORAGE RESERVOIR*

| Year | pH | Total salts, per cent |
|---|---|---|
| 1940 | 8.50 | 0.0470 |
| | **8.20 | 0.0590 |
| 1941 | 9.06 | 0.0510 |
| 1942 | 8.40 | 0.0467 |
| 1943 | 8.60 | 0.0690 |

* Data supplied by the Soils Research Laboratory, Swift Current.
** Samples from main canal.

FIGURE 11. General view of the Greasewood Area at Val Marie, early spring of 1938. Snow water is lying in some low spots.

*The Movement of Saline Salts*

The possibility existed that irrigation might cause an upward movement of salts from the subsoils of the Greasewood Area resulting in a severe salinity problem. This could have been caused by evaporation due to the inability of irrigation water to penetrate, by evaporation of excess irrigation water because of poor drainage or by the development of high water tables. A careful check was kept at a few selected locations to determine if the salt content was increasing or decreasing from year to year. Analytical data from one of these locations are given in Table 16. The samples were taken as close together as possible from year to year and, although somewhat obscured by the extreme variability which is found in salt content within short distances, the data indicate that a downward movement of salts is in progress.

TABLE 16.—MOVEMENT OF SALTS—GREASEWOOD AREA, VAL MARIE*

| Sample depth (ins.) | pH July 1941 | pH July 1942 | pH Sept. 1943 | Total salts in per cent July 1939 | Total salts in per cent July 1940 | Total salts in per cent July 1941 | Total salts in per cent July 1942 | Total salts in per cent Sept. 1943 |
|---|---|---|---|---|---|---|---|---|
| 0 – 6 | 8.15 | 8.40 | 8.16 | 0.174 | 0.252 | 0.131 | 0.130 | 0.152 |
| 6 – 12 | 8.25 | 8.40 | 8.35 | 0.494 | 0.237 | 0.093 | 0.123 | 0.197 |
| 12 – 24 | 8.05 | 8.07 | 8.06 | 1.889 | 1.937 | 0.717 | 1.559 | 1.176 |
| 24 – 36 | 8.00 | 7.90 | 7.97 | 1.557 | 1.802 | 1.788 | 1.196 | 1.695 |

* Data supplied by the Soils Research Laboratory, Swift Current.

FIGURE 12. Greasewood Area in 1941 after being established to perennial forage crops. Note stacks of hay.

## LARGE SCALE SEEDINGS OF FORAGE CROPS

Most of the Greasewood Area was seeded to oats in 1938 as a test crop and to determine the need for further levelling. Additional levelling was done on most blocks during the 1939 season so that most of the area was in condition to seed to perennial forage crops in the spring of 1940. In the meantime, crop tests had been conducted on the experimental area and information secured on methods of obtaining stands of small seeded crops. The results served as a basis for the seedings made in 1940. Altogether, 940 acres were sown that spring, mostly broadcast, and, with a few exceptions, the resulting stands were excellent. The crops seeded were alfalfa, sweet clover, slender wheatgrass, brome and crested wheatgrass alone and in mixtures with each other. Almost two-thirds of the established stands were lost later in the season due to a beet webworm infestation. Some of this land was reseeded in the late fall and the balance the following spring. By the end of the 1941 season, 830 acres had been established to perennial forage crops and by the end of the 1943 season this figure had risen to 1,025. The remaining 300 acres of land in the Greasewood Area were still in the developmental stage.

Of the crops and mixtures seeded, not all were equally satisfactory. As an example, where fields were seeded to a grass or grasses alone, the yields dropped sharply in a year or two. Alfalfa was seeded in some fields where surface drainage was not complete because the land was so flat. These stands of alfalfa were gradually thinned down and had to be reseeded to grasses. A number of fields were seeded to grass-alfalfa mixtures and these were the most satisfactory from a yield standpoint.

## DISCUSSION

The original soil survey of the Val Marie Irrigation Project pointed out that the soils of the Greasewood Area would probably have definite crop limitations and be difficult to handle under irrigation. Settlers who had been in the district for many years had always considered that this land was worthless as they had never seen a grass cover on it and they did not think it possible to grow cultivated crops even with irrigation. The experiments and tests conducted from 1938 to 1943 demonstrated that there were a limited number of crops which could be grown after methods of establishing stands had been determined. Some of these did not produce well while others returned fair yields. The yield of alfalfa was satisfactory where the land was properly levelled and where there was enough slope to provide good surface drainage. The yield of grass-legume mixtures also was a promising feature. Because of the high costs of land cultivation and the yields obtained from annual crops, it seems reasonable to conclude that this area and any similar areas should be devoted exclusively to the production of perennial forage crops as hay, pasture or seed. This type of crop production would yield the highest returns with the lowest cost of production.

There have been differences of opinion expressed as to whether or not soils of this nature should be brought under irrigation considering the expense involved, the difficulties of bringing them into production and the crop yields obtainable. It should be remembered that these soils are worthless in their native state and are actually a liability to the community in which they occur. If they can be brought under irrigation and made to produce reasonable yields of crops, they become an asset. When such soils occur in regions where severe droughts are frequent, under irrigation they may materially assist in the stabilization of agriculture in the region by producing feed reserves.

Where these heavier soils constitute part of an irrigable area where better soils also occur, the better soils should be developed first. They are capable of greater diversification and are easier to manage. The heavier soils should only be developed as the need arises.

It would seem desirable for governments to assume the responsibility and financial costs of developing such land, releasing it to settlers only after it has been satisfactorily established to suitable crops. Following this, close supervision should be maintained and technical assistance provided to ensure that the land continued to be properly managed.

## SUMMARY

1. An account is given of investigations conducted on the heavy textured saline soils of the Val Marie Irrigation Project in Southwestern Saskatchewan from 1938 to 1943. In the native state these soils were dominated by greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.), were low in fertility, in poor physical condition and contained moderate to heavy amounts of saline salts. The soils dispersed on wetting and formed a hard surface on drying and were impermeable to water. Similar greasewood areas exist elsewhere in Canada and the Western United States in association with irrigable lands.

2. A major problem was determining a satisfactory method of obtaining stands of small seeded crops. Broadcast seeding on a ruffled soil surface was found to be most successful.

3. A wide range of crops was tested and those found to be best adapted to the soil and climatic conditions were alfalfa, sweet clover, slender wheatgrass, brome grass, crested wheatgrass, meadow fescue and Reed canary. Oats, millet, sorghum, tall oatgrass, creeping red fescue, timothy and alsike clover were valuable also. It was concluded that perennial forage crops were most suitable and economical for crop production on these soils and among those crops grass-alfalfa mixtures were generally preferable to grasses alone, which were low yielding, or alfalfa alone, which was only satisfactory where complete surface drainage was possible.

4. Commercial fertilizers and other soil amendments tested generally failed to significantly increase crop yields. Fall ploughing increased the yield of annual crops as compared to spring ploughing.

5. Since the topography of the land was extremely flat, proper land levelling and provision for adequate drainage was particularly essential. Large heads of water were required for irrigating and three to four irrigations were needed annually for perennial crop production. Both the border ditch and border dike methods of irrigating were found to be satisfactory.

6. Poor penetration of irrigation water was obtained when the soils were first brought under irrigation but improved when oats, grass and grass-legume mixtures were grown for three or four years. Penetration was still poor following several years of growing alfalfa.

7. Soil analyses indicated a wide variation in soluble salt content which was high enough in some locations to depress yields. Over a five-year period, there were indications that irrigation was resulting in a downward movement of salts. The quantity of soluble salts carried by the irrigation water used was negligible.

8. It was concluded that, with proper management and the use of suitable crops, these heavy textured soils could be successfully brought under irrigation, and thus materially assist in stabilizing the agriculture of drought areas. Complete development by governments of similar land would appear to be desirable and subsequent settlement should be closely supervised.

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# THE LEPTURINI OF AMERICA NORTH OF MEXICO

## PART III. CORTODERA[1]

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The genus *Cortodera* has proved to be a difficult group in the matter of finding reliable characters to separate the species. This has made it advisable to delay the publication of the revision until such time as the material became adequate. The death of the senior author in 1941 was also a deterrent factor and it was some time before the junior author could put the revision in its final form.

### *Cortodera* Mulsant.

1863, Hist. Nat. Coleopt. de France, Longicornes, Ed. 2, pp. 572-575. *Leptacmaeops* Casey, 1913, Mem. on the Coleopt., IV, p. 230.

Casey correctly separated these species from *Acmaeops*, evidently on their elongate form. They are, however, separated from *Acmaeops* by a much better character and that is the closed cell in the anal sector of the wings,[3] which places them in the group with *Pachyta*, *Centrodera*, *Anthophylax*, etc. The *Anoplodera*, *Typocerus*, *Acmaeops* group do not have this cell.

Since the publication of Part I of the *Lepturini* the authors have obtained seven species of *Cortodera* from Europe. Some of them are so close to ours that it would be rather difficult to separate them in a key. However, it seems more important to identify our North American species and leave interfaunal comparisons for the future.

The tempora of all the American species of this genus are more or less inflated or swollen and the sides of the prothorax feebly angulate or rounded. Compared with *Acmaeops* the form is more elongate, although occasionally small females might be taken for *Acmaeops*. About 25 species are listed from Europe and Asia. The genotype of *Leptacmaeops* is *longicornis* (Kirby), designated by Casey.

Many species are dichromatic in both sexes and the elytra may be either black or flavous with dark vittae. In some species, the elytra may be entirely black or black with base ferruginous, in others entirely black or entirely flavous. The colour is constant only in a few species, and larger series may show these to have variants. Punctation is also quite variable in some species, especially between the sexes, and in these cases the variations in size of punctures cannot be depended upon. Possibly this may be influenced by the food supply, or the climatic conditions at the time of emergence.

[1] Contribution No. 2379, Division of Entomology, Science Service, Dominion Department of Agriculture, Ottawa, Canada. Parts 1 and 2, by J. M. Swaine and Ralph Hopping, were published as Bulletins 52 and 85, respectively, National Museum of Canada, Ottawa, Canada.

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[3] See Swaine, J. M., and Ralph Hopping, 1928. The Lepturini of America north of Mexico, Pt. I. National Mus. of Canada, Bul. 52, Biol. Series No. 14, p. 89, pl. 11.

## KEY TO THE SPECIES OF CORTODERA

1. Hind trochanters with a distinct marginal angle near the inner distal end (Figure 5); metasternum of male with a tubercle on each side of mid-line near posterior margin (except *sierrae* and *placerensis*); tip of aedeagus turned up (except *sierrae* and *placerensis*), apex usually blunt, rounded (Figures 1, 2)..... 2
   Hind trochanters evenly rounded to apex (Figure 6); metasternum of male without tubercles; tip of aedeagus not turned up, apex usually sharp (Figures 3, 4). (Males of *C. robusta* not seen).....10

2. Disc of pronotum nearly impunctate, highly polished, virtually glabrous, evenly inflated and almost without indication of a median, longitudinal depression .....*impunctata*
   Disc of pronotum densely and/or coarsely punctate, except for a narrow, longitudinal, median, smooth area..... 3

3. General appearance of pronotal disc dull (20X), the punctures dense, almost or quite contiguous, nearly evenly spaced except for median longitudinal smooth area; surface between punctures usually microreticulate, opaque..... 4
   Pronotal disc distinctly shining, the punctures unequally distributed though they may be fairly close together; surface between punctures polished, not microreticulate..... 7

4. Length 11 mm. or over (Sierra Nevada Mts. of California); males lacking metasternal tubercles, tip of aedeagus not turned up..... 5
   Length 7 to 10 mm. (San Francisco Bay region of California, coasts of Oregon and Washington) males with tubercles on metasternum, tip of aedeagus turned up... 6

5. Elytra with side margins convergent from base to apex; elytral bases rufous (only males seen, northern Sierra Nevada Mts.).....*placerensis*
   Elytra with side margins parallel; elytral bases not rufous (Southern Sierra Nevada Mts.).....*sierrae*

6. Front margin of pronotum straight, anterior transverse sulcus usually very shallow, sides of pronotum not tuberculate; elytral vestiture nearly half as long as a median antennal segment; pronotal vestiture of male long, erect, fine; of female shorter, largely appressed, thicker; front legs of male black (Corvallis, Ore., to Olympia, Wash.).....*militaris*
   Front margin of pronotum anteriorly arcuate, anterior transverse sulcus usually distinct; sides of pronotum subtuberculate at about anterior third; elytral vestiture shorter, hardly a quarter as long as a median antennal segment; pronotal vestiture of male rather short, sub-erect; of female short, decumbent; front legs of male red (Coast of California from Santa Cruz north).....*berkeleyensis*[4]

7. Elytra black, without longitudinal vittae, sometimes with elytral bases rufous; disc of pronotum usually feebly inflated, longitudinal median depression feeble or absent..... 8
   Elytra either entirely black, black vittate with yellow, or yellow with black vittae, never with elytral bases rufous; disc of pronotum usually strongly inflated with shallow median longitudinal depression..... 9

8. Elytra with bases rufous; surface dully shining.....*oregonensis*
   Elytra entirely black, surface strongly shining.....*harneyensis*

9. Males with metasternal tubercles very prominent, nearly precipitous posteriorly; females with tempora strongly inflated; vittate forms of both sexes always with lateral marginal vitta of elytra yellow.....*bakeri*
   Males with metasternal tubercles prominent but more conical, not precipitous posteriorly; females with tempora feebly inflated; vittate forms of both sexes always with lateral marginal vitta of elytra black.....*longicornis*

10. Pronotum with long erect vestiture.....11
    Pronotum with short appressed vestiture.....12

11. Sutural interlocking flange of elytra strongly explanate toward apices (elytra slightly spread to see); elytra of male strongly shining, without long vestiture..*nitidipennis*
    Sutural flange of elytra feebly or not explanate toward apices; elytra of male not strongly shining, vestiture long as in female.....*subpilosa*

[4] The authors have seen specimens from McLoud and Medford, Ore., which indicate that *C. berkeleyensis* may be a well defined subspecies of *militaris*.

12. Elytral apices evenly rounded to suture; punctation at base of elytra not much coarser and sparser than that of rest of elytra.....13
Elytral apices subtruncate, sutural margins feebly produced; punctation at base of elytra sparse and unequal, unlike that of rest of elytra.....16

13. Pronotum strongly inflated, deeply transversely impressed behind.....*spuria*
Pronotum feebly inflated, not deeply transversely impressed behind..... 14

14. Sides of head nearly parallel behind eyes then suddenly rounded to neck, colour black except legs and epipleurae which may be rufous in part.....*coniferae*
Sides of head evenly and fully rounded behind eyes; colour black or with elytra, testaceous or vittate.....15

15. Pronotum without distinct lateral angles; elytra testaceous (only males seen)..*stolida*
Pronotum with distinct lateral angles; entirely black or with elytra testaceous with black vittae (only females seen).....*robusta*

16. Base of prothorax 1.5 times wider than apex; elytra usually luteous, rarely fuscous or piceous with yellow base; aedeagus apically gradually narrowed to tip..*basalis*
Base of prothorax only 1.3 times wider than apex; elytra usually entirely black or with base reddish-yellow, more rarely almost entirely yellow; aedeagus broader apically, more suddenly narrowed to tip (Figure 3).....*cubitalis*

### *Cortodera impunctata* n. sp.

Body strongly shining, either entirely black or with elytra black with two yellow vittae, these last sometimes expanded to occupy most of elytra. The length varies from 8.5 to 11.5 mm.

*Holotype* male: Length 9 mm.; breadth across humeri 2.5 mm. *Head* black, clypeal suture strongly impressed, clypeus nearly impunctate on apical half, basal punctures fine, sparse, separated by considerably more than their widths; front with irregularly spaced, fine punctures widely separated, with a triangular impunctate area between the arms of the frontal suture; coronal suture moderately impressed on the vertex extending back nearly to the pronotum; tempora fully and evenly rounded; occipital punctation very irregular in size but punctures generally much larger than those on the front or clypeus and almost contiguous; antennae nearly as long as the body, dark brown, the first and second segments combined shorter than the third which is longer than the fourth and a little shorter than the fifth. *Pronotum* without longitudinal sulcus with sides strongly angled before the middle and then convergent from the angles backward, apical transverse sulcus more deeply impressed than the basal one, both apical and basal beads well defined; disc nearly impunctate, highly polished and shining, punctures at sides of pronotum about the same size as those on occiput but more widely separated and irregular. *Elytra* coarsely punctate basally, the punctures separated by considerably more than their widths, gradually becoming finer posteriorly until they are very fine toward the apices; lateral margins sub-parallel, apices evenly rounded to the sutural angles which are not acute; each elytron with a yellow longitudinal vitta not quite attaining base and apex, broader than sutural black vitta, but narrower than marginal black stripe, slightly more expanded at apical fourth. Entire dorsal vestiture so short as to be unnoticed. *Under-surface* with fine sparse vestiture, metasternal tubercles well defined and the angles of the metatrochanters prominent; femora black, tibiae and tarsi dark brown.

*Allotype* female: Length 9 mm.; breadth across humeri 3.0 mm. *Head* more densely punctate than in the male, antennae about two-thirds the body length; body broader in proportion to length, markings much as in male, but yellow vittae a little broader, a little more expanded at apical fourth; metasternal tubercles lacking, metatrochanter angles nearly as prominent as in the male. Otherwise as in the male.

*Holotype*, Wenatchee, Washington v-8-'08, No. 5359, and *allotype*, same label data as holotype, No. 5360, in the California Academy of Sciences, Ent., San Francisco. *Paratypes* 13; 2 males, Wenatchee, Wash., v-8-'08 in collection of I. W. Bales, Yakima, Wash., 1 male, 1 female, Ellensburg, Wn. v-8-1932 Wm. W. Baker Coll., sent to the latter at Puyallup, Wash.; 1 male, 1 female, Virden, Wash., v-18-1935, and v-28-1932, respectively, in the Canadian National Collection, Ottawa; remaining paratypes from Ellensburg, Thorp and Wenatchee, Washington, in the Hopping Collection, Vernon, B.C.

Thirty specimens have been examined, 29 from Washington and 1 from Oregon. Of these, 13 are vittate and 17 are black. This dichromatism occurs in both sexes. Superficially, the species resembles *longicornis* but can be distinguished easily from that species by the highly polished, nearly impunctate disc of the pronotum in *impunctata*, in contrast to the rather densely punctate disc of *longicornis*. The latter species has a longitudinal median shallow sulcus on the pronotum which is lacking in *impunctata*.

*Cortodera placerensis* n. sp.

Body black except elytral bases which may be ferruginous; in one specimen this reddish area has almost disappeared leaving obscure reddish spots on humeri and near scutellum. Antennae brown, more ferruginous at base; legs mainly rufous, tarsi blackish.

*Holotype* male: Length 10.5 mm.; breadth across humeri 3.2 mm. *Head* black, mandibles reddish with black tips, palpi black; clypeus rather sparsely and finely punctate basally, punctures separated by more than their widths, becoming impunctate toward apex; front densely and finely punctate, punctures separated by less than their widths; frontal suture faintly evident, coronal suture distinct between antennal bases, extending as an impunctate line a little over half way back to thorax from vertex; occipital region faintly shining, densely, moderately finely punctate, punctures separated by less than half their widths; tempora evenly rounded; vestiture of head short, appressed, with longer erect hairs on the tempora. *Pronotum* feebly shining, about as wide as long, the sides angled at apical third, sub-parallel behind the angles; apex with fairly well developed bead, the posterior one fainter medianly, becoming well developed at the lateral posterior angles; punctation of disc about as coarse and dense as on the occiput, a little finer and denser on the sides, with a feeble longitudinal median impression in which there is an impunctate narrow line not attaining base and ending a little over half way between base and apex; vestiture of prothorax flavous, short and appressed. *Elytra* about two and two-thirds longer than wide, the sides rather strongly convergent from base to apex, with a basal ferruginous band about 1 mm. wide, the remainder black,

dully shining, punctures coarse and separated by less than their widths on basal third, finer and more widely separated on humeri and bordering scutellum; punctures finer and denser on apical two-thirds; apices evenly, broadly, rounded externally then straight transverse to the sutural angles which are not sharp; vestiture flavous, short, decumbent. *Under-surface* with sparse gray pubescence, finely punctate, transversely carinulate on prosternum; metasternum without tubercles near the median posterior margin, last ventral abdominal segment feebly emarginate; metatrochanters with angle on inner distal margins well developed.

*Holotype* male, Placerville, Cal., 6-1932, F. T. Scott collector, No. 5370, in the California Academy of Sciences, Ent. San Francisco. One *paratype*, Tahoe City, Cal., viii-6-1922, coll. by Weld, is in the Canadian National Collection, Ottawa.

Only these two males have been seen. *C. placerensis* resembles *oregonensis* but can be easily distinguished from that species by the absence of metasternal tubercles which males of *oregonensis* have. In common with *sierrae*, it has the angles on the metatrochanters but lacks the metasternal tubercles. The aedeagus is also of the *sierrae* type *i.e.*, the sides nearly parallel to near the tip then abruptly rounded to the point which is short, not sharp, and not turned up. It may be distinguished from *sierrae* by the more convergent sides of the elytra, coarser punctation of head and prothorax, basal rufous band on elytra, and sides of prothorax behind the angles more parallel.

### *Cortodera sierrae* n. sp.

Body either entirely black (male) or with elytra and parts of legs brown (female).

*Holotype* male: Length 10.5 mm.; breadth across humeri 3.2 mm. *Head* black except mandibles which are reddish-brown; clypeal suture deeply impressed and feebly arcuate; clypeus rather coarsely punctate on basal two thirds, punctures separated by about their widths, apical third nearly impunctate; punctation of front a little finer than on clypeus; irregular and with a triangular space below frontal suture, impunctate; coronal suture well defined between antennae and extending back to a line even with hind margins of eyes; posterior portion of this suture bordered by a small, irregular, impunctate area, remainder of occipital region densely, fairly regularly, coarsely punctate, the punctures contiguous or nearly so; tempora evenly, moderately fully rounded; antennae not more than three fourths the body length, the basal segments blackish becoming brown distally, the third segment as long as the first and second combined, longer than the fourth and shorter than the fifth. *Pronotum* black, nearly as wide as long, moderately inflated, longitudinal median depression feebly indicated, anterior and posterior beads poorly developed, sides fairly evenly rounded with faint suggestion of angles before the middle; disc dull, densely punctate, punctures about the same size as those on occipital region of head, nearly or quite contiguous. *Elytra* black, faintly shining, lateral margins parallel, apices rather fully rounded to suture; punctation at base much coarser than on pronotum, separated by a little less than their

widths on posterior region; dorsal vestiture short and inconspicuous. *Under-surface* entirely black, vestiture longer than on dorsum, more conspicuous, but fine and sparse; metasternum without tubercles; last ventral abdominal segment narrowly emarginate at tip; angle of metatrochanter blunt but distinct; femora black, tibiae and tarsi dark brown; apical third of aedeagus broader than basal portion then suddenly rounded near the tip and straight transverse to the short, blunt terminal point.

*Allotype* female: Length 11.0 mm.; breadth across humeri 3.5 mm. Somewhat stouter than the male, the elytra brown, opaque, dorsal vestiture much longer and more evident; coronal suture not evident behind the antennae (terminal segments missing); pronotum a little broader in proportion to length than in the male; under-surface black, legs mostly brown, femora blackish distally; angle of metatrochanter feebly indicated; otherwise as in male.

*Holotype* male, Huckleberry Mdw., July 8, 1911, No. 5361, and *allotype* female, Giant Forest, Tulare Co., Calif., Aug., No. 5362, in the California Academy of Sciences, Ent., San Francisco. One paratype female, Camp 6, May 20, '09 in the Hopping Collection, Vernon, B.C. Localities of holotype and paratype are both in Fresno Co., California, the former near General Grant National Park, the latter near a logging camp of the Hume Bennet Lumber Company.

Two other specimens, one in the F. T. Scott Collection and one in the F. E. Blaisdell Collection, are slightly teneral but seem to be this species. *C. sierrae* differs from other known species except *placerensis* because it lacks the metasternal tubercles although possessing the angle on the metatrochanters. *C. placerensis* has much more tapering lateral margins to the elytra than *sierrae* and males of the latter species, as far as known, have not rufous elytral bases as in the males of *placerensis*. The aedeagus of *placerensis* is not as broad as in *sierrae* nor so suddenly rounded near the tip, and the terminal point is longer.

### *Cortodera militaris* Leconte

1850 Journ. Ac. N.S. Phila. I (2) : 322.

The type of this species has been carefully compared with specimens from Washington and Oregon by Dr. H. C. Fall and the senior author. The type has the vestiture of the pronotum slightly matted. The red shoulders so common in this species make it resemble *cubitalis*, but the two may be easily distinguished by the more robust form and the long vestiture of the pronotum in *militaris* and the lack of it in *cubitalis*. However, this species is dichromatic in both sexes as is *cubitalis* and may be entirely black without red shoulders or flavous without red shoulders. The type of *militaris* has black antennae. The specimens at hand are from Seattle, Wash., southward to the Willamette Valley of Oregon. Fifty-seven specimens have been seen, 22 from Washington and 35 from Oregon. The Willamette Valley specimens differ from those from Washington in vestiture and punctation, but there seems to be no definite character to indicate a distinct species. More material may make it advisable to recognize at least a good subspecies here.

*Cortodera berkeleyensis* n. sp.

Body either entirely black or with elytra testaceous. Both sexes dichromatic *i.e.*, elytra black or testaceous. Front legs usually red, middle and hind pair black, occasionally all legs black. The length ranges from 7 to 10 mm.

*Holotype* male: Length 7.5 mm.; breadth across humeri 2.4 mm. *Head* black, mandibles reddish-brown; labrum testaceous in distal portion; basal two thirds of clypeus rather densely and medium coarsely punctate, the punctures nearly or quite contiguous toward the base giving rise to moderately long hairs; apical third of clypeus glabrous; clypeal suture nearly straight, deeply impressed; front confusedly rugose punctate; frontal suture scarcely evident; coronal suture faintly evident between the antennal bases only, not extending behind the antennae at all; occipital region densely punctate, the punctures practically contiguous, coarser than those on the clypeus; tempora short, evenly and fully rounded; antennae not quite the body length, dark brown. *Pronotum* black, longer than wide, scarcely at all inflated and without definite longitudinal median depression but with a longitudinal median glabrous line, widest posteriorly extending from near the base almost to apex; apical and basal margins without definite bead; lateral tubercles prominent, placed before the middle; punctures of disc not quite so coarse as on the occiput, not quite contiguous. *Elytra* black, lateral margins slightly convergent from base backward, evenly rounded to suture at apices; punctation much coarser than on head or thorax, becoming somewhat finer on apical third; punctures at base separated by less than their widths; elytra more shining than head or pronotum; vestiture of dorsum short and inconspicuous. *Undersurface* with sparse fine pubescence more condensed on meso- and metepisterna; metasternal tubercles only moderately prominent, blunt, subconical; front femora and tibiae reddish-brown, tarsi blackish; middle legs black except extreme bases of femora and apices of tibiae which are reddish-brown. Hind legs black except for small reddish area at base of femora; angle of metatrochanter well defined but not acute.

*Allotype* female: Length 8.0 mm.; breadth across humeri 2.7 mm. Colour about as in the male; antennae only two thirds the body length; punctation of pronotum more dense than in the male, the punctures contiguous; form more robust, otherwise as in the male, except that the female, of course, lacks the metasternal tubercles and the angle on the metatrochanters is less prominent.

*Holotype* male, Berkeley, Calif. iv-12, E. G. Linsley collector, No. 5363, and *allotype* female, same label data as above, No. 5364, in the California Academy of Sciences, Ent., San Francisco. *Paratypes* 12, same label data as types: 1 male, 1 female, California Academy of Sciences, San Francisco; 1 male, 1 female collection of E. G. Linsley, Berkeley, California; 1 male, 5 females and two additional males from Richmond and Berkeley, A. T. McClay collector, in the Hopping Collection, Vernon, B.C.

This species is closely related to *C. militaris*, but differs in vestiture as shown in the key. In addition, the tempora of *berkeleyensis* are more fully rounded than in *militaris* and the side tubercles of the pronotum are more pronounced. Most predominantly black specimens of *militaris* have red shoulders which have never been seen in the black phase of *berkeleyensis*.

*Cortodera oregonensis* n. sp.

Body black with red crescentic patches occupying elytral bases; legs predominantly reddish in males, in the female the front pair reddish, the other legs predominantly black. Length from 9.4 to 12.5 mm.

*Holotype* male: Length 9.4 mm.; breadth across humeri 2.9 mm. *Head* black, mandibles dark reddish-black; clypeus irregularly, sparsely punctate, with irregular glabrous areas and a few long setae; front rugose punctate, the frontal suture indicated by a triangular glabrous area, the space between this and the antennal sockets on the vertex finely punctate; coronal suture clearly defined on the vertex but not deep, extending back to a line joining the hind margins of the eyes; occipital region very densely punctate, dull, the punctures contiguous, larger toward the margins of the eyes; tempora rather fully rounded to thorax; antennae about three fourths the body length, dark brown, the third segment considerably longer than the first and second segments combined, much longer than the fourth and about equal to the fifth. (Terminal two segments on left antenna missing.) *Prothorax* black, the sides definitely angled before the middle, a little convergent backward from the angles; anterior and posterior transverse depressions shallow, front margin without bead, hind margin feebly, narrowly beaded; disc feebly inflated, without median longitudinal depression, but with an irregular glabrous median area extending from near the base for two-thirds the distance to the apex; punctures about the size of those on the head but more widely separated, irregularly spaced, more densely placed toward the sides. *Elytra* black with red humeri, the posterior margin of each spot arcuate anteriorly; lateral elytral margins sub-parallel, apices evenly rounded to suture and briefly explanate; elytral punctures much coarser than on thorax on basal fourth, separated by about their widths, becoming gradually finer toward the apices; dorsal vestiture short and inconspicuous with the exception of a few long hairs on tempora and sides of thorax. *Under-surface* black, with fine sparse pubescence not much more condensed on metepisterna; metasternal tubercles not prominent, blunt and rounded; angle on metatrochanters only moderately pronounced; front legs rufous, the tarsi somewhat dusky; middle legs with reddish femora, the tibiae blackish basally, reddish distally and tarsi black; hind legs with femora rufous except distal fifth which is black, tibiae and tarsi black.

*Allotype* female: Length 12.5 mm.; breadth across humeri 4.0 mm. Coloration as in male except that middle and hind legs are entirely black; elytra broader in proportion to length than in the male; the tempora less fully rounded; pronotum more inflated on the disc with longitudinal median impression feebly indicated, otherwise as in the male, except for sexual characters.

*Holotype* male, Ashland, Ore., 6-17-35 No. 5365, and *allotype* female Sparta, Ore., Baker Co., vii-1922, No. 5366, in the California Academy of Sciences, Ent., San Francisco. One paratype male, McLoud, Ore., 5-27-35, returned to Fred Lawrence, Medford, Ore.

This species superficially resembles *placerensis* but possesses metasternal tubercles which the latter species lacks. *Oregonensis* might also be confused with *militaris* and *cubitalis* but it lacks the long vestiture of the former and is much more robust than the latter and does not have truncate elytral apices which distinguishes *cubitalis*.

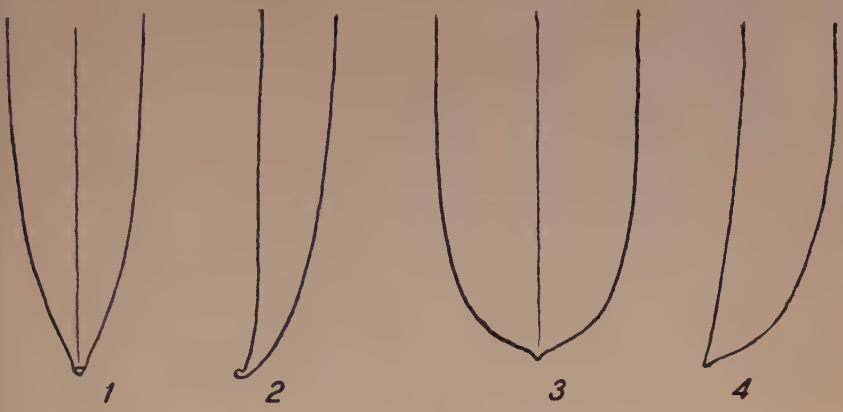
*Cortodera harneyensis* n. sp.

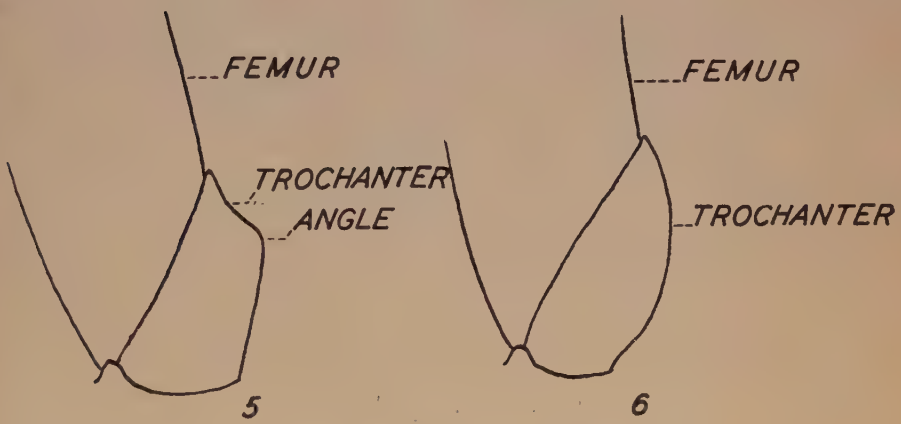
Body entirely black, strongly shining, antennae and legs ferruginous.

*Holotype* male: Length 8 mm.; breadth across humeri 2.3 mm. *Head* with clypeal suture moderately impressed; clypeus densely punctate along base, more sparsely so toward the middle and impunctate, shining, along the front margin; front with a few punctures just above the clypeal suture and near the antennal sockets, with the central area nearly devoid of punctures; frontal suture faintly indicated, coronal suture faint between antennae, extending back about one third the distance from antennal bases to thorax; occipital area densely punctate, punctures separated by about half their widths; tempora rather fully and fairly evenly rounded; antennae with fourth segment equal in length to first and second combined, a little shorter than the third, the fifth longer than any (terminal 3 segments missing from right antenna). *Pronotum* a little longer than wide, feebly and evenly rounded at sides, with well defined, broad basal collar, faint bead at apex, and feeble basal bead; disc moderately convex, with a shining, longitudinal, impunctate, median strip extending from the base to the middle, the bordering punctures separated by about their widths, becoming more dense toward the sides; scutellum punctate basally, becoming nearly impunctate toward the tip. *Elytra* not quite three times longer than broad, with sides feebly convergent from base to apex; punctures very coarse, somewhat irregular in size on basal half, separated in most cases by their widths, finer and more widely separated on apical half; lateral margins rather broadly rounded to apices, with a faint suggestion of truncature. *Prosternum* transversely carinulate, remainder of undersurface finely punctate, episterna densely so and more densely clothed with fine gray appressed vestiture; ventral vestiture otherwise rather sparse and fine; metasternal tubercles well defined; last ventral abdominal segment narrowly feebly emarginate at tip. Legs with first three tarsal segments densely padded with gray hairs; angle on inner distal margin of metatrochanters not strongly developed.

*Holotype* male, Stein Mts., Harney Co., Ore. June 7-24, '22, W. J. Chamberlin coll., No. 5369, in the California Academy of Sciences, Ent., San Francisco. One *paratype* male, same label data as above, sent to W. J. Chamberlin, Oregon State College, Corvallis, Ore.

Only the male of this species has been seen. Although it is coupled with *oregonensis* in the key, it resembles a small black specimen of *longicornis*. It may be distinguished from that species by its smaller size, its




EXPLANATION OF FIGURES

Figures 1, 2. Apical half of aedeagus of *Cortodera oregonensis* n. sp., dorsal and lateral views. Figures 3, 4. Same, of *C. cubitalis* (Lec.). Figure 5. Hind trochanter and base of femur of *C. oregonensis* n. sp. Figure 6. Same, of *C. cubitalis* (Lec.).

less strongly convex pronotum, the sides of which are less strongly rounded, its more shining elytra and by having the angle of the metatrochanter less strongly developed.

*Cortodera bakeri* n. sp.

Body rather strongly shining, entirely black, or with a flavous longitudinal vitta on each elytron, lateral elytral margins flavous; some black specimens have a flavous spot at the base of each elytron near the scutellum; antennae brown to blackish; legs rufous, middle and hind pair sometimes black but usually with femora rufous, tibiae and tarsi of middle and hind pair rufous to brown.

*Holotype* male: Length 10 mm.; breadth across humeri 2.8 mm. *Head* black with clypeal suture moderately impressed; clypeus rather densely and moderately finely punctate, the punctures as wide as spaces between them; front more densely punctate with frontal suture faintly

evident; coronal suture also faint extending half the distance from eyes to thorax; occipital portion of head very densely and a little more coarsely punctate than clypeus, the punctures separated by less than half their widths, coarser and more widely separated on the genae; tempora evenly and rather fully rounded to thorax; vestiture of head short and appressed with a few longer erect hairs; antennae nearly as long as the body, ferruginous, scapes black on anterior sides; third segment longer than the first and second combined, also longer than the fourth and about equal to the fifth. *Prothorax* black, as long as wide; front margin of pronotum strongly beaded, posterior margin faintly beaded medianly, strongly beaded laterally, strongly sinuate; sides feebly angled just before the middle, the disc densely punctate, moderately convex with a shallow longitudinal line not quite attaining the apex or base; vestiture rather sparse, short and appressed with a few scattered longer erect hairs. *Elytra* two and one-half times longer than broad, strongly shining, coarsely punctate, more finely so along the suture and toward the apices, very coarsely so just behind the humeri where the punctures are separated by about their widths, on other portions separated by more than their widths; sides nearly straight, moderately convergent from base to apex, evenly rounded to apices which are faintly produced; ornamented on each elytron with a flavous longitudinal vitta not quite attaining the base, nearly interrupted at basal sixth, and joining at the apex with a flavous vitta which runs forward along the lateral margin, narrowing as it approaches the humerus; vestiture short, sparse, and pale. *Under-surface* black, finely and moderately densely punctate, with moderately long, fine, rather sparse gray vestiture which becomes very dense on the episterna; longitudinal keel on anterior portion of metepisternum strongly developed; tubercles on each side of median line near posterior margin of metasternum very prominent, angle on inner distal margin of metatrochanters strongly indicated; front legs ferruginous except extreme tip of femora and tarsi which are blackish; middle femora ferruginous at base, blackish distally, tibiae blackish basally becoming ferruginous distally and the tarsi blackish; hind femora ferruginous basally, remainder of hind legs black.

*Allotype* female: Length 10 mm.; breadth across humeri 3.2 mm. Differs from the male in its broader form in proportion to length, by having the side margins of elytra more parallel, and the subsutural vittae are not constricted at basal sixth; base of prothorax broader in proportion to apex than in the male; antennae about three fourths the body length; metasternum without tubercles; otherwise as in the male.

*Holotype* male, Rainier Nat'l For., Wn., v-30, 1935; Hell's Crossing, S. E. Crumb collector, No. 5367, and *allotype* female, Rainier Nat'l For., Wn., vi-9-1935, Currant Flat, Wm. W. Baker Collr., No. 5368, in the California Academy of Sciences, Ent., San Francisco. *Paratypes* 16: 2 males and 4 females to W. W. Baker, Puyallup, Washington; 2 males and 2 females to the Canadian National Collection, Ottawa; 1 male and 5 females in the Hopping Collection.

Seventeen specimens have been examined from Tieton, Signal Peak, Tampico, Rimrock and Rainier National Forest, all in Washington. Both sexes are dichromatic, some being vittate, and some with the body entirely

black. The length varies from 8 to 11 mm. This species closely resembles *longicornis* Kby. and can easily be mistaken for that species. *C. bakeri*, averages smaller in size, shorter in proportion to breadth than *longicornis*, the elytra not so coarsely punctate, more shining, not so convex, the metasternal tubercles more prominent in the males. The aedeagus is narrower than in *longicornis*, more acuminate and more strongly turned up at the tip.

### *Cortodera longicornis* Kirby

1837, Fauna Bor. Am., Pt. IV, p. 185.

*marginalis* Lec., 1857, Rept. Expl. Survey Miss. to Pacific, p. 28.
*vincta* Lec., 1861, Proc. Acad. Nat. Sci., Phila., p. 346.
*ligata* Lec., 1873, Smithson. Misc. Coll., Pt. II, No. 264, p. 211.
*punctiventris* Csy., 1913, Mem. on the Coleopt., IV, p. 238.
*alticola* Csy., 1913, Mem. on the Coleopt., IV, p. 239.
*suturalis* Csy., 1924, Mem. on the Coleopt., XI, p. 277.
*dorsalis* Lec., 1859, List of Coleopt. of Kansas and New Mexico, Smithson. Cont. Knowl. XI, p. 21.

Length 10 to 14 mm. The great variation in colour has led to several synonyms, especially in the forms without vittae. The species may have elytra wholly testaceous or flavous, vittate or entirely black. In the north the colour seems to be generally darker, while in the south the lighter colour predominates, *i.e.*, the form known as *ligata* Lec. Various colour forms have been taken in copulation. The types have been examined of all the forms included in the synonomy. Mr. Leng also recognized these as all one species, as in his "Synopses of Cerambycidae," 1890, under *A. ligata* p. 108, he says "I am of the opinion that the three last named species *longicornis*, *vincta* and *ligata* should be united under the oldest name, *viz. longicornis* Kby." The rather elongate form with coarse punctures of the pronotum and elytra distinguishes this species.

Five hundred and forty-three specimens are before us from Colorado, British Columbia, Alberta, Washington, Oregon, California, Nevada and Montana.

In literature, Utah, Kansas, Nebraska, and Montana are given.

Type locality: "Lat. 65°."

### *Cortodera nitidipennis* Casey

1913, Mem. on the Coleopt. IV, p. 236.

Length 9 to 13 mm. This species although here recognized as distinct from *subpilosa* Lec. is rather doubtfully distinct, but averages larger and is more shining, although rubbed specimens of *subpilosa* are often just as shining. Both species are found on the common sunflower, *Balsamorrhiza sagittata* Nutt.

Fifty-six specimens are before us from Oregon and Idaho.

Type locality: Washington State.

### *Cortodera subpilosa* Leconte

1850, Jour. Acad. Nat. Sci., Phila. (2) I, p. 322.

*lupina* Lec., 1860, Proc. Acad. Nat. Sci., Phila., XII, p. 321.
*intermedia* Csy., 1913, Mem. on the Coleopt. IV, p. 236.
*pugetana* Csy., 1913, Mem. on the Coleopt. IV, p. 237.
*quadriceps* Csy., 1913, Mem. on the Coleopt. IV, p. 237.

Casey's consideration of the subpilosa group was based on only 19 specimens, an insufficient number to determine variations; 504 specimens are before us from California, Oregon, Montana, Wyoming, Washington, Alberta, Saskatchewan and British Columbia.

In literature Utah and Kansas are given.

Type locality: "Oregon".

### *Cortodera spuria* Leconte

1873 Smithsonian Misc. Coll., No. 264 (2) : 228-229.

In the original description, Leconte characterized *Leptura spuria* on p. 228 as "*nigra*", named from a pair from "Oregon and Washington Territory". But on p. 223 of the same paper he keys it out as "Prothorax not longer than wide, more densely punctured, elytra and legs testaceous . . . spuria."

In the Leconte Collection there is a testaceous specimen marked type of *spuria* in Henshaw's (?) writing. No black specimens are present nor can we find any specimens marked *spuria* in the Casey, Horn, or Ulke Collections. The testaceous specimen marked "type" bears the label "W.T." and although Leconte in his description says "Oregon and Washington Territory", Mr. W. S. Fisher informs us that "W.T." often meant merely Western Territory in 1873; but there is no date on the type and there is no telling when the specimen was collected.

The only specimens before us which compared with that one marked "type" in the Leconte Collection are one from Colorado and one from Arizona. In order to clear up this matter, we are herewith accepting the specimen marked "type" in the Leconte Collection as the type of *Cortodera spuria* Lec. Although there have been extensive collections made in Oregon and Washington of late years, nothing has been collected in those states that could possibly be construed as *spuria* as represented by the "type" and Leconte's key.

As the original description is not readily obtainable we are here giving it in full.

"*L. spuria.* Nigra, cinereo-pubescens, capite thoraceque confertim subtiliter punctatis, hoc antice posticeque constricto, convexo, subcanaliculato, lateribus postice parallelis, antice obliquis, angulis posticis subprominulis; elytris parallelis, apice rotundatis, sat fortiter punctatis. Long. 11 mm.

"Oregon and Washington Territory; one pair. The antennae in the male are slender, nearly four-fifths the length of the body; scarcely more than half the length of the body in the ♀.

"This and *L. cubitalis* form a peculiar group in the genus, having the eyes scarcely emarginate on the inner margin, the 3rd joint of the tarsi broader and more deeply bilobed than usual, agreeing in these characters with Acmaeops; the head is much less constricted behind than in other Lepturae although it is suddenly narrowed, and the angles are rectangular and rounded, almost as in Encyclops; the front is, however, not vertical, the transverse impression is deep, the genae rather short, the epistoma and mouth moderately long; the last joint of the palpi is but feebly dilated, and squarely truncate, longer than the preceding, as usual.

"I would associate these species with the 2nd division of Acmaeops, but the antennae seem to be inserted rather behind the line joining the front of the eyes, as in other Lepturae, and the general appearance is more suggestive of the latter genus. They would, however, be equally well placed in either."

*Cortodera coniferae* n. sp.

Form black, basal segment of antennae, epipleurae, front legs and bases of middle and hind femora usually rufous. Range in length 7.8 to 9 mm.

*Holotype* male: Length 7.0 mm.; breadth across humeri 2.3 mm. *Head* black, mandibles reddish; clypeus rather coarsely and fairly regularly punctate, the punctures extending almost to the distal margins, separated by about their widths; clypeal suture straight, deeply impressed; frontal suture enclosing a triangular impunctate area, remainder of front regularly punctate, the punctures finer than on the clypeus; coronal suture deeply impressed on vertex extending back to a point a little behind a line between the hind margins of the eyes but much less strongly indicated behind vertex; punctation of occipital region very dense, regular, punctures about the size of those on clypeus but contiguous; sides of head nearly parallel behind eyes then suddenly rounded to neck; antennae not more than three fourths the body length; scapes rufous, remainder dark brown, the third segment about equal to the first and second segments combined, longer than the fourth but much shorter than the fifth. *Pronotum* black, about as long as wide, the sides definitely angled slightly before the middle, feebly convergent from the angles backward; front and hind margins narrowly and not strongly beaded; punctures on disc about the size of those on head but more widely separated and irregularly spaced with a median longitudinal impunctate line, the margins of which are not clearly defined; punctures become contiguous toward base of pronotum and more dense on the sides; anterior and posterior transverse depressions very shallow. *Elytra* black except epipleurae which are dark reddish-brown; lateral margins parallel, evenly and fully rounded to suture at apices; punctation considerably coarser than on pronotum, separated by about their widths, not varying much in size on the anterior two thirds, becoming finer toward apices; dorsal pubescence fairly long but fine, appressed, and inconspicuous. *Ventral surface* finely punctate with fine appressed sparse pubescence not appreciably more condensed on metepisterna; front legs rufous except tarsi which are dark brown; middle and hind legs with femora rufous at extreme base, remainder of legs blackish.

*Allotype* female: Length 9.0 mm.; breadth across humeri 3.0 mm. *Head* broader than in the male, coronal and frontal sutures more clearly defined; antennae proportionately nearly as long as in the male. *Pronotum* more inflated on the disc, the longitudinal median depression more evident, the posterior margin much more sinuate. Otherwise as in the male.

*Holotype* male, Midday Val., Merritt, B.C., vi-19-'23, R. Hopping No. 5714, and *allotype* female, Midday Val., Merritt, B.C., vii-8-'24, N. L. Cutler, No. 5714, in the Canadian National Collection, Ottawa. *Paratypes* 6: 1 male, Midday Val., Merritt, B.C., vii-3-1924, K. F. Auden, and 1 female, same label data as above, in the California Academy of Sciences, Ent., San Francisco; 2 males, 1 female, same locality as above, K. F. Auden and N. L. Cutler, in the Hopping Collection, Vernon, B.C.

This species is not likely to be confused with any other. The colour is remarkably constant and no dichromatism is evident in the 21 specimens

which have been examined, all from British Columbia except 1 from Colorado, and 1 from Washington. Quite a number were collected in cheesecloth cages enclosing samples of *Pinus ponderosa* and *Picea engelmanni*. Either one or both of these trees may be the host.

### *Cortodera stolida* Casey

Mem. on the Coleopt. XI, 277, 1924.

Length 10 to 10.5 mm. A single specimen in our collection answers Casey's description very well. Both the type and this specimen, males, differ from anything else in the medium length of the rather dense elytral vestiture, which is yellow or practically the same colour as the elytra, and in the fine elytral punctation. It is probably nearer *spuria* than any other species, but is more slender and the pronotum is not nearly so inflated.

Type locality: Las Vegas, Nevada.

One male, Stockton, Utah, is in the Hopping Collection. The type in the Casey Collection has also been examined.

### *Cortodera robusta* n. sp.

Colour entirely black with brown antennae, or with flavous elytra with black vittae, brownish antennae and ferruginous forelegs, middle and hind femora also sometimes ferruginous at bases.

*Holotype* female: Length 10.5 mm.; breadth across humeri 3.5 mm.; black with dark brown antennae. *Head* with clypeus glabrous on the apical half, rather finely punctate on basal half, distances between punctures equal to puncture widths; front rugose-punctate, frontal suture evident but confused by a few coarse punctures; more finely and densely punctate on vertex; coronal suture obscure, faintly evident but confused by punctation for half the distance between vertex and thorax; occipital reg on very densely and moderately finely punctate, the punctures contiguous; tempora very fully rounded; vestiture very short and inconspicuous on occiput, with a few scattered longer hairs on tempora. *Pronotum* wider than long, the sides distinctly angled before the middle, parallel behind the middle, without distinct apical or basal bead except toward the sides; very densely and more coarsely punctate than the head, with a slightly impressed, smooth, impunctate, longitudinal line extending from near the base for two-thirds of the distance to apex; vestiture very short, decumbent, inconspicuous; disc rather feebly convex. *Elytra* with parallel sides, only a little over twice longer than wide, punctures on basal half coarser than on the thorax, separated by about their widths, becoming considerably finer on the apical half; apices very fully rounded to the sutural angle; vestiture short, gray, inconspicuous; scutellum nearly glabrous. *Prosternum* transversely carinulate, meso- and metasternum finely and rather densely punctate, denser on the episterna; punctures on ventral abdominal surface a little coarser and more widely separated; front and middle coxae finely rugose-punctate, metatrochanters with no appreciable angle on the inner margin; vestiture of under-surface short, gray, decumbent.

*Holotype* female, Vantage, Wn., v-24-32, Wm. W. Baker Coll. No. 5371, in the California Academy of Sciences, Ent., San Francisco. Paratypes 2: same label data as above, one in the Canadian National Collection, Ottawa, the other sent to Wm. W. Baker, Puyallup, Washington. The last paratype mentioned is the vittate form. In this specimen the black vittae are not entire, extending from the humeri for two-thirds the distance to apices, where they fade out; the sutural margins are also dusky, the legs ferruginous. The other paratype is black as in the type but smaller, 8.7 mm.

*C. robusta* is probably closer to *sierrae* than to any other species, but can be distinguished by the absence of the angle on the metatrochanter which is present in *sierrae*. The form of *robusta* is much shorter in proportion to the breadth. In the key it runs to *stolida* but can be distinguished from that species by the much more robust form and more fully rounded elytral apices. (Only females seen.)

### *Cortodera basalis* Leconte

1873, Smithson. Misc. Coll., Pt. II, No. 264, p. 211.

*dichroma* Csy., 1913, Mem. on the Coleopt., IV, p. 231.
*auricollis* Csy., 1913, Mem. on the Coleopt., IV, p. 232.
*elegantula* Csy., 1913, Mem. on the Coleopt., IV, p. 232.
*cuneata* Csy. 1913, Mem. on the Coleopt., IV, p. 231.
*minima* Csy., 1913, Mem. on the Coleopt., IV, p. 233.

Length 7 to 11 mm. In colour the elytra vary from black with base of humeri rufous or testaceous, to wholly testaceous except the extreme tips black. The males often have the vestiture entirely denuded.

In the *basalis* group in the Casey Collection there is only one he considers *basalis*, from Santa Cruz, Calif. His *auricollis* is represented by four females and the other species by colour variations.

The Leconte type of *basalis* has the prothorax with long reddish vestiture and the elytra black with base reddish. Of the balance of his series Nos., 2, 3 and 6 are not *basalis*. Forty-five specimens are before us from California.

Type locality: "California".

### *Cortodera cubitalis* Leconte

1850, Jour. Acad. Nat. Sci., Phila. (2) I, p. 322.

*temporalis* Csy., 1913, Mem. on the Coleopt., IV, p. 233.
*quadrinotata* Csy., 1913, Mem. on the Coleopt., IV, p. 233.
*tenuis* Csy., 1913, Mem. on the Coleopt., IV, p. 233.
*variipes* Csy., 1913, Mem. on the Coleopt., IV, p. 234.

Length 8 to 10 mm. Leconte's type has the apices of the elytra sinuate, subtruncate, which does not seem to occur in any other species except *basalis*. In Casey's *cubitalis* group his *tenuis* has wholly black elytra and pale front legs. His 4 specimens of *temporalis* from Lake Co., Calif., have a narrow prothorax almost denuded of vestiture; they are typical males of *cubitalis*. Casey's specimens under *cubitalis* are both females with black elytra and prothorax wider than long. His *variipes* from California, 3 in number and probably slightly teneral, differ only in the antennae being brown.

Casey's *variipes* and *cubitalis* are evidently the same species, females, and his *tenuis* and *temporalis* evidently males of *cubitalis*. Wholly black specimens are very common in this genus. Specimens with red humeri are often called *militaris* but may be distinguished by the shape of the hind trochanters.

Fifty-one specimens are before us, all from California.

Type locality: "San Mateo, Calif".

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